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In Selectively Cut Stands Of Spruce And Fir In Maine And Northern New Hampshire

by

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FEAR OF WIND DAMAGE

THE CONIFEROUS FORESTS of northern Maine and New Hampshire are composed principally of red spruce (Picea rubens) and balsam fir (Abies balsamea) in varying proportions.

Of the associated species, northern white-cedar (Thuja occidentalis) is usually present on moist sites; paper birch (Betula papyrifera), white spruce (Picea glauca), eastern white pine (Pinus strobus), and eastern hemlock (Tsuga canadensis) occur commonly on somewhat better drained soils. Sugar maple (Acer saccharum) and yellow birch (Betula alleghaniensis)[2] are found with increasing frequency on the drier and deeper soils on middle slopes. Red maple (Acer rubrum) is common throughout.

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[2]Nomenclature of species follows Little, Elbert L. Jr., Check list of native and naturalized trees of the United States (including Alaska). U.S. Dept. Agr., Agr. Handb. 41. 472 pp. 1953.

Some form of partial cutting has been recommended for most forest types in which red spruce and balsam fir and their softwood associates are present in commercially operable quantities. Ideally, the single-tree selection system offers the greatest potentialities for attaining and maintaining a desirable stand structure, for several reasons:

1 True uneven-aged stands are characteristic of these types.

2 Both red spruce and fir are tolerant species.

3 Reproduction of both species comes in well naturally as long as a substantial overhead canopy is maintained.

4 The more desirable red spruce can be held in at least equal ratio to the less desirable fir only if a continuous forest cover and a source of spruce seed are maintained.

5 Because of differences in longevity of the two species (fir should be operated on a rotation of 70 years, while red spruce matures anywhere between 100 and 250 years), a short cutting cycle is desirable to maintain maximum growth and to salvage fir losses.

While the theoretical desirability of the single-tree selection system is gradually becoming accepted by practicing foresters, there is a general fear that extensive wind damage will result. This fear is based partly upon the undeniable facts that many soils on which spruce and fir occur are shallow, and that both species are typically shallow-rooted (7, 2, 10).[3]

However, reliable recorded evidence either for or against wind damage following careful partial cutting is virtually nonexistent for this region. To a large extent the meager references in the literature are based upon more or less casual observation of stands cut to rather low diameter limits. For example, Linn (5) reported on the results of what was apparently rather poorly controlled cutting in New Hampshire, and asserted that only in the mixedwood type was there any point in leaving any merchantable spruce and fir; in the softwood types all residual trees were blown down. Similarly Robertson (8) reported that in Quebec "The larger balsam fir left after logging succumbed to wind and fungus"; and on the strength of this observation he advises

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[3] Underlined numbers in parentheses refer to Literature Cited, page 17.

against partial cutting in the pure softwood types. But he adds, "Beyond the pure softwood type, there is no room for clear-cutting methods." Much the same sentiment was voiced by Dana (2), who cautioned against windfall but did not present any data to indicate the seriousness of the danger.

Actual measurements of damage were reported on by Behre (1) and Kelly and Place (4). Behre studied wind damage after cutting to diameter limits in the Adirondacks and concluded that cuttings of this kind could be made without materially increasing liability to windfall. He recorded about 3 percent of the spruce and 9 percent of the fir trees blown down in softwood types, and 5 percent of the spruce and 17 percent of the fir damaged in spruce-fir-hardwood types. Kelly and Place reported on a study at the Acadia Forest Experiment Station in south-central New Brunswick. They found only 5 percent of the basal area of spruce and fir lost to windfall in the 3 years following partial cutting in the softwood type. The cut took out about 70 percent of the merchantable volume and the authors concluded that if a lighter cut were made wind losses could be reduced materially.

EXPERIMENTAL CUTTINGS

Beginning in 1946 a series of experimental cuttings were made on five areas (table 1) in the spruce-fir region of Maine and New Hampshire. These studies, undertaken by the Northeastern Forest Experiment Station in cooperation with timberland owners, were designed primarily to test partial cutting as a means of controlling the spruce budworm (Choristoneura fumiferana Clem.). One of the concomitant objectives was to appraise the wind damage to residual growing stock.

Within each area, permanent 1/5-acre sample plots were established before cutting. All trees 3.6 inches d.b.h. and larger were tallied by 1-inch diameter classes. Stand-stock tables were prepared to serve as a basis for drawing up marking rules.

The principles of the tree-selection system around which marking rules were built have been described by Westveld (11) and McLintock (6). Briefly, the objectives were to provide an operable cut of the mature and poor-risk trees and at the same time to leave a vigorous growing stock that would withstand the imminent spruce budworm epidemic, be resistant to windthrow, and return a high rate of interest.

Table 1.--Description of experimental cutting areas

Item	Area				
	T5 R18	Johnson Mountain	T11 R4	TE R2	Phillips Brook
Size..........acres..	295	159	140	314	338
Sample plots..........number..	72	54	33	73	94
Area sampled..........percent..	4.9	6.8	4.7	4.6	5.6
Year cut..........	Fall 1947	Winter 1946-47	Summer 1948	Summer 1948	Winter 1947-48
Year re-examined..........	Fall 1951	Summer 1951	Summer 1951	Fall 1950	Fall 1951
Time since cutting..........years..	4	4½	3	2¼	3½
Original volume of spruce-fir 5.6 inches d.b.h. and larger...rough cords per acre..	15.2	8.6	13.4	8.3	25.4
Volume of spruce-fir cut........rough cords per acre..	8.8	4.0	3.9	4.8	7.1
percent..	58	47	29	58	28
Original basal area of all species 3.6 inches d.b.h. and larger..........square feet per acre..	142	109	131	116	133
Basal area cut, all species......square feet per acre..	31	16	25	19	25
percent..	22	15	19	16	19
Degree of cutting—					
in softwood type..........percent..	25	65	90	20	85
in mixedwood type..........percent..	75	35	10	70	15
in hardwood type..........percent..	0	0	0	10	0

To do this, the cutting method chosen was designed to: (1) favor fast-growing or potentially fast-growing trees; (2) increase the proportion of spruce to fir; and (3) improve spacing and diameter-class distribution. The cutting operation was carried out by the regular logging crews employed by the cooperating companies in the course of the season's operations. As is customary, only spruce and fir were cut. The volumes removed for each area are shown in table 1.

The five areas were scattered widely over the region; hence the forest stand structures varied a great deal. Also, prevailing logging practices and the attitudes of woods workers to new cutting methods differed. For these reasons there were some deviations from what might have been considered "normal" procedure.

1 On the Phillips Brook area the marking procedure departed from the usual recommendations in one respect. A considerable amount of large but fast-growing fir was left. This was done deliberately to find out whether such trees were a good risk with respect to both wind damage and the budworm. Ordinarily no fir above 9 inches d.b.h.---and few above 8 inches d.b.h.---would be left.

2 The Johnson Mountain tract was severely overcut in a number of places because of labor difficulties over which the company had no control. The result was the removal of between 80 and 100 percent of the merchantable volume on about one-fifth of the area. The trees below 6 inches d.b.h. were thus left vulnerable to wind, ice, and snow damage.

3 On the T5 R18 tract, unfamiliarity of woods labor with "yarding" operations made it necessary for the company to "stump-cut" the area. "Stump-cutting" is a local term for cutting the wood and piling it virtually at each stump. Single-horse sled roads are then cut to each pile, the roads ordinarily averaging 50 or 60 feet apart. In "yarding", the wood is skidded in tree lengths to main haul roads, which are laid out at about 400-foot intervals. The latter is obviously a much better system for silvicultural purposes in all except stands suitable for true clear-cutting. The result of stump-cutting in this case was that much more area than should have been was opened up for roads and landings.

After cutting, plots were re-measured to determine the exact amount cut on each. Examinations for wind losses[4] were made 2 to $4\frac{1}{2}$ years after cutting. At that time the diameter and species of each tree damaged, and the nature of the damage--i.e., whether broken or uprooted--were recorded. From these data, and from the stand records for each plot before and after cutting, comparative summaries and analyses of wind losses in relation to stand conditions were prepared.

RESULTS

Extent Of Loss

Wind damage was evaluated in several ways. In the first place, losses of merchantable-sized trees were computed in rough cords. To the timberland owner or woods manager this is of first importance, because the volume losses sustained could have been avoided by cutting all merchantable material. Indeed, it is this very argument that often is uppermost in the mind of the forest owner who is considering any system of management that calls for leaving timber capital on the stump.

Secondly, a comparison was made between basal area lost to wind and total basal area of the stand after cutting. To the forester, this is of more significance than merchantable volume. It conveys a better idea of the seriousness of wind losses, because it includes the submerchantable 4- and 5-inch classes as well as trees of pulpwood size. It also gives a better picture of losses in relation to the structure of the entire stand--and not just to the spruce-fir component. It is worth pointing out that, whatever the losses of these smaller trees under the selection system, the loss would certainly have been much greater under a clear-cutting.

Finally, the losses were computed as a percentage of the residual growing stock. The data have been converted both to a per-acre and to a per-acre-per-year basis. They are given in terms of spruce-fir volume of trees 5.6 inches d.b.h. and larger, and of total basal area of all species 3.6 inches d.b.h. and larger (table 2).

Note that the greatest loss in volume and basal area occurred on the Phillips Brook area during the $3\frac{1}{2}$ years

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[4]UNLESS SPECIFIED OTHERWISE, THE TERM 'WIND LOSS' IN THIS REPORT MEANS 'NORMAL' LOSSES FROM WIND ACTION, AS OPPOSED TO LOSSES DUE TO CATASTROPHES SUCH AS HURRICANES.

Table 2.--Summary of wind damage to spruce-fir after partial cutting on experimental areas

Area and item	Time since cutting	Trees lost: 4-5 inches	Trees lost: 6 inches and up	Trees lost: Total	Basal area lost in trees 4 inches and up		Volume lost in trees 6 inches and up	
	Years	Number	Number	Number	Square feet	Percent	Rough cords	Percent
T5 R18	4							
Total per acre		3.05	4.10	7.15	2.09	1.9	0.49	7.7
Per acre per year		.76	1.03	1.79	.52	.5	.12	1.9
Johnson Mountain	4½							
Total per acre		8.15	4.44	12.59	2.13	2.3	.31	6.7
Per acre per year		1.81	.98	2.79	.47	.5	.07	1.5
T11 R4	3							
Total per acre		1.36	3.78	5.14	1.32	1.2	.30	3.2
Per acre per year		.45	1.26	1.71	.44	.4	.10	1.1
TE R2	2¼							
Total per acre		1.23	1.43	2.66	.54	.6	.09	2.6
Per acre per year		.62	.72	1.34	.27	.3	.05	1.4
Phillips Brook	3½							
Total per acre		4.79	5.48	10.27	3.43	3.2	.85	4.6
Per acre per year		1.37	1.56	2.94	.98	.9	.24	1.3
Average, all areas	3½							
Total per acre		3.72	3.85	7.57	1.90	1.8	.41	5.0
Per acre per year		1.00	1.11	2.11	.54	.5	.12	1.4

after cutting. Here 0.85 cord of spruce and fir (4.6 percent of the residual spruce-fir stand) was destroyed by wind. This represents an annual loss of nearly ¼ cord per acre, slightly more than the estimated average yearly increment for unmanaged stands of this type. Similarly, the 3.43 square feet of basal area lost per acre constituted 3.2 percent of the growing stock in trees 3.6 inches d.b.h. and larger.

As mentioned earlier, the cutting on this tract departed from the recommended procedure in that many large but fast-growing fir trees were left. Of the 0.85 cord per acre lost to wind action, 0.47 cord (55 percent) was made up of balsam fir more than 9 inches d.b.h. Such trees would normally be cut. If these trees were disregarded, the loss would be 0.38 cord since cutting, or 0.11 cord per acre per year.

The number of trees blown down on the Johnson Mountain tract is worthy of note--nearly 13 per acre in the 4½ years since cutting. Sixty-five percent were in the 4- and 5-inch classes. This reflects the heavy and uncontrolled cutting that characterized the early stages of this operation, and that often left only a few scattered trees above

the merchantable limits. In such spots all remaining trees were then particularly vulnerable to wind and snow breakage.

To illustrate: On the 25 plots where 25 percent of the total basal area (and 56 percent of the merchantable spruce-fir volume) was cut, all the 4- and 5-inch trees were lost--88 of them. In addition, 36 larger trees were lost. In contrast, on the other 29 plots, where only 6 percent of the basal area (and 24 percent of the spruce-fir volume) was cut, no small trees were lost. Here only 12 larger trees were lost.

The lightest damage occurred on the TE R2 tract, where losses per acre since cutting have been 0.09 cord or 0.54 square foot of basal area. This represents an annual loss to wind of 0.4 percent of the basal area or 1.1 percent of the spruce-fir volume.

Of incidental interest is the proportion of each area, as estimated from the sample plots, that sustained no damage at all. This is summarized as follows:

Plot	No damage (Percent)
Johnson Mountain	37
T5 R18	43
Phillips Brook	55
T11 R4	58
TE R2	66

The fact that of the area on Johnson Mountain and T5 R18 only 40 percent (average) was undamaged by wind as compared to 60 percent (average) for the other three areas is undoubtedly another reflection of the cutting operations themselves.

Relationship Of Wind Loss To Degree Of Cutting

The wind losses of spruce and fir, in relation to change in stand density resulting from cutting, have been summarized in table 3. The cut is expressed in total basal area of all species 3.6 inches d.b.h. and larger, rather than in volume of spruce-fir removed. This is because basal area provides a more accurate picture of all the material removed in logging. Not only the merchantable pulpwood trees are included, but also all trees of all species, down to and including the 4-inch class (trees cut in clearing roads and landings).

Table 3.--Relation between percentage of total basal area cut and wind damage on 1/5-acre sample plots, for an average period of $3\frac{1}{2}$ years

Area	Percentage of total basal area cut							
	0	1-10	11-20	21-30	31-40	41-50	51-60	61-70
				Total volume lost per acre, in cords				
T5 R18	—	0.47	0.61	0.46	0.59	0*	0*	—
Johnson Mountain	0.21	.24	.18	.19	1.13*	—	0.63*	1.70*
T11 R4	.03	0	.18	.35	.35	1.65*	1.00*	.35*
TE R2	0	.03	.06	.17	.32	0*	0*	--
Phillips Brook	.12	.26	.43	1.14	1.31	.97	.42	.50
Average, all areas	.10	.22	.30	.68	.95	1.02	.41	.85
				Total basal area lost per acre, in square feet				
T5 R18	—	1.85	2.49	1.96	2.35	0.23*	0.22*	—
Johnson Mountain	0.94	0.98	1.15	2.49	6.91*	—	5.76*	16.87*
T11 R4	.14	0	.74	1.68	1.61	6.72*	3.54*	3.13*
TE R2	.16	.30	.35	1.02	1.44	.22*	0*	--
Phillips Brook	.42	.92	1.71	5.68	6.46	4.80	1.60*	1.75*
Average, all areas	.43	.89	1.33	2.78	3.62	3.61	2.72	7.25

*Fewer than 4 plots represented.

The relation between percentage of cut and wind damage appears to be rather erratic when individual areas are considered. This is due in part to the effects of off-plot cutting on damage within plots. For example, in T5 R18 there was no increase in damage with increase in cutting. This is explainable largely by the fact that this area was stump-cut; nearly 20 percent of the area was opened up to roads and yards as compared with an average of less than 10 percent in the normal yarding operations. Thus many plots that had been cut only lightly were situated next to roads or yards that provided openings where wind could get at the trees. Much the same situation was true of the Johnson Mountain tract, where 20 percent of the area was clear-cut.

On the other hand, damage rose steadily on the Phillips Brook tract from 0.42 square foot of basal area in undisturbed portions to 6.46 square feet where 30 to 40 percent of the basal area had been cut.

When all areas are considered together, a trend becomes apparent, in both basal area and volume (fig. 1). Where the cutting took more than 30 percent of the basal area, cumulative losses over an average period of about

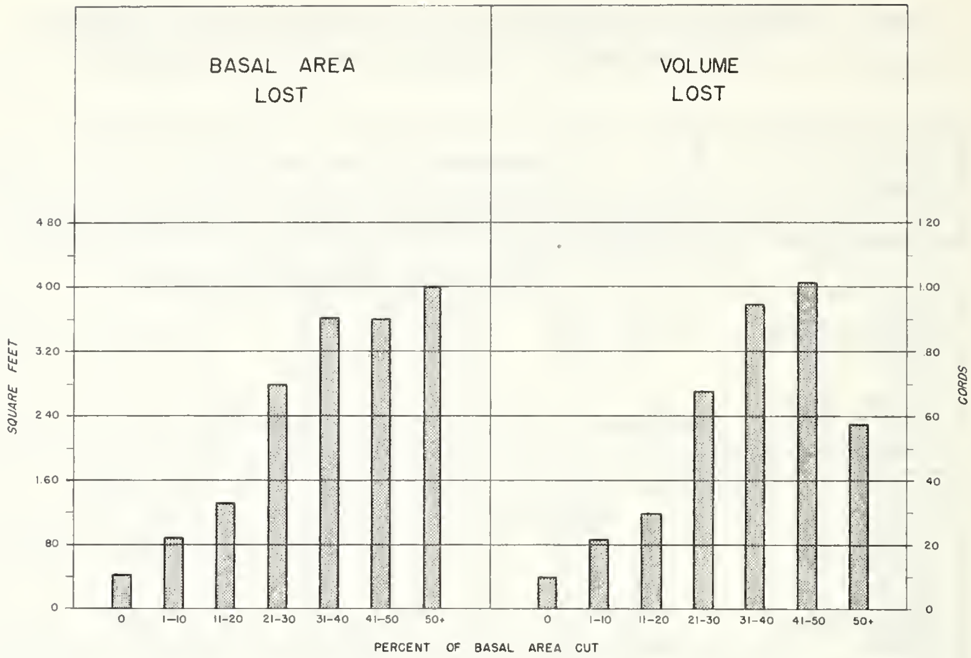

Figure 1.--The relationships between basal area cut and volume lost to wind damage. These are based on 1/5-acre sample plots, for an average period of 3½ years.

3½ years since logging amount to 3.66 square feet of spruce and fir per acre (0.89 cord). Where the cutting did not exceed 20 percent, losses to wind averaged about 0.96 square foot of basal area (0.22 cord). It will be observed that even where there was no cutting at all, "normal" wind losses have amounted to 0.43 square foot per acre (0.10 cord) during the same period.

The relationships of forest type and degree of cutting to wind damage are shown in table 4. In T5 R18 and TE R2 the losses per acre per year were the same for both types. In these two areas the percentage of cut was also very similar for the two types, being about 3 percent more in the softwood type. This comparison is of interest because some people have contended that selective cutting may be feasible in the mixedwood type where associated hardwoods help protect the residual softwoods, but that in the softwood type the remaining trees will all blow down.

On Johnson Mountain, losses in the mixedwood type were half those in the softwood type. But the proportion of basal area cut in the former was less than one-fourth of what it was in the latter; so the difference in damage does not appear to be correlated with type. On the Phillips Brook

Table 4.--Percentage of basal area cut as related to basal area lost by wind, by areas and types

Area	Basal area cut in original stand		Basal area lost per acre per year	
	Mixedwood type	Softwood type	Mixedwood type	Softwood type
	Percent	Percent	Square feet	Square feet
T5 R18	21.0	23.7	0.52	0.52
Johnson Mountain	5.7	20.5	.29	.58
T11 R4	0	19.7	0	.45
TE R2	15.9	18.5	.24	.24
Phillips Brook	24.5	17.8	1.13	.73
Average, all areas	17.2	20.2	.47	.62

area, on the other hand, losses were considerably greater in the mixedwood type than in the softwood type. But here again, the average percentage of cut--greater in the mixedwood type--appears to be the important factor. When all areas are considered together the parallelism is seen again: the slightly greater losses in the softwood type appear to be a reflection of percentage of cut, which was greater there than in the mixedwood type.

The Nature Of Wind Damage

In four out of five of the areas, uprooting was more common among spruce, and breakage was the principal type of injury in fir (table 5). The averages for all areas are 34 percent of the spruce broken, as compared with 61 percent of the fir. These relationships are very much in line with the well-recognized susceptibility of fir to butt rot, which weakens the tree and is indirectly the cause of a high percentage of fir mortality (3, 9).

This leads naturally to the question: Is fir more susceptible to wind damage than spruce? Since fir is more abundant on all study areas than spruce, the answer to this question is found in a comparison of the proportional losses sustained by the two species (table 6).

In every case the amount of fir lost in relation to the amount of growing stock left after cutting was greater than corresponding spruce losses. The difference in volume destroyed ranges from twice as much fir as spruce on T5 R18

Table 5.--Percentage of total number of trees damaged by uprooting and by breakage on each area, for spruce and fir

Area	Spruce		Balsam fir	
	Uprooted	Broken	Uprooted	Broken
T5 R18	69	31	43	57
Johnson Mountain	60	40	27	73
T11 R4	67	33	71	29
TE R2	80	20	32	68
Phillips Brook	64	36	45	55
Average, all areas	66	34	39	61

Table 6.--Relative susceptibility of spruce and fir to wind damage, expressed as percentage of number of trees and of volume destroyed since cutting

Area	Wind damage			
	Percentage of number of trees		Percentage of volume in cords	
	Spruce	Fir	Spruce	Fir
T5 R18	3.2	3.8	5.2	11.8
Johnson Mountain	2.0	8.6	2.9	10.9
T11 R4	0.4	3.0	0.7	5.0
TE R2	.9	3.4	1.5	4.1
Phillips Brook	3.8	6.5	1.5	6.8
Average, all areas	2.3	5.3	2.2	7.2

to seven times as much on T11 R4: Taking all areas together, fir losses were 5.3 percent of the number of trees and 7.2 percent of the volume. Spruce losses were 2.3 percent and 2.2 percent respectively.

The extreme susceptibility of large fir trees to wind damage has already been mentioned. Data from the Phillips Brook area show that fir losses in the residual growing stock amounted to 2.9 percent in the 6- to 9-inch classes inclusive, but in the 10-inch and larger classes 11.3 percent of the trees were destroyed. Eighteen percent of the fir 12 inches d.b.h. and larger were blown down--almost one tree out of every five.

CONCLUSIONS

It is obvious, of course, that losses did occur in spite of efforts to prevent them. One of the objectives of silviculture is to reduce the amount of natural loss to the merchantable, or potentially merchantable, components of the stand. If the cutting practices tested in these studies are to be recommended, ways should be found to reduce the losses from wind to an acceptable amount.

No recommendations can be made as to the percentage of merchantable spruce and fir volume that it is safe to cut. The effect of opening the stand on wind damage is much better expressed in terms of basal area. Thus it was found that wind losses increased with severity of cut as expressed by the percentage of total basal area removed, including trees of all species 3.6 inches d.b.h. and larger. On the basis of these studies it seems unwise to remove more than 25 percent of the total growing stock (as expressed in basal area) at any one time. If this and other precautions are followed, wind losses can probably be kept to less than 0.05 cord per acre per year.

The make-up of the residual stand, especially the amount and size of the fir component, is at least as important as the percentage of cut. A large volume in fir trees more than 8 inches in diameter increases the probability of loss regardless of the amount of material removed. The Phillips Brook area is a good case in point: losses were heavier there than in any of the other areas studied in spite of the fact that the percentage of merchantable volume cut was the lowest. But the residual stand contained 10.9 cords of fir per acre, much of it in trees 8 to 12 inches d.b.h.

The susceptibility of fir to decay and wind breakage is illustrated by the fact that, of the 212 fir trees that were broken on the five areas, virtually every one had butt rot. Many 9- and 10-inch fir trees had been carefully considered at the time of marking, and were left as good risks; yet they blew down, and every one was found to have either butt rot or decay in the roots. By contrast, only 25 spruce trees were broken. This consideration is of such importance that any fir tree larger than 8 inches d.b.h. should be rated a poor risk with respect to wind, regardless of its apparent condition as indicated by external appearances.

Another aspect of tree size should be mentioned. No tree of either species should be left whose crown extends more than a few feet above the general level of the canopy

after the stand has been cut. One of the biggest sources of loss among spruce was the sound, full-crowned, vigorous individuals, some of them 15 and 16 inches in diameter, that had been left for future growth. The trouble was that they were too tall. Before cutting, their dominant position was not a hazard because other dominants afforded protection. But once these were removed, the crown of the remaining tree, projecting 10 or 15 feet above the new canopy level, was a prime target for the wind. Such trees should be cut. An exception to this rule would be isolated "superdominants", provided they had been isolated before cutting and were known to have a certain degree of windfirmness.

There is nothing to indicate that softwood types are inherently any more vulnerable to wind damage after partial cutting than mixedwood types. The critical factor seems to be the proportion of basal area removed in the logging operation. To be sure, the presence of other species--red maple, white-cedar, paper birch, pine, and other common associates--which are not cut may help prevent windthrow. And in a pure spruce-fir stand the percentage of merchantable volume cut will usually have to be less than that cut in stands where associated species are present. It is also reasonable and logical to suppose that danger of windthrow is greater on shallow, wet soils than on deep, well-drained soils. But on the other hand, mixedwood types--occurring as they do on slopes--are often more exposed to winds. Also, observations of fir cut on many logging operations throughout the region suggest that fir is more susceptible to butt rot on well-drained soils than on wet soils. However, these matters were not carefully tested; the above comments are based primarily on observation and inference.

Another factor of importance is the manner of logging--already mentioned--and its effect on the size of openings. Extreme care should be used in leaving trees immediately adjacent to yards and road junctions. Here long-crowned spruce trees of dominant and codominant crown classes are particularly vulnerable, as are tall, slender fir trees. Short trees with rapid taper and crown ratios of from 3 to 5 are safest to leave along openings of this sort. Once the wind takes out a few trees along a road or landing it is likely to keep working back into the stand.

This brings up the matter of logging methods. The T5 R18 tract was stump-cut; and while the cutters adhered very well to the marking between roads, 20 percent of the total land area was converted to sled roads, haul roads, and landings. This left ample openings for wind action. Aside from the other drawbacks of this system of cutting, the danger from wind loss is much greater. Similarly, close

supervision of the logging crew to assure cutting only of marked trees is necessary. Extensive wind losses resulted from overcutting on the Johnson Mountain area, where adequate supervision was impossible.

It is suspected from the nature of the damage on the Johnson Mountain area in spots that had been heavily cut, that snow was responsible for a substantial part of the destruction of small fir. The 4-, 5- and 6-inch trees left scattered over an otherwise clear-cut area no longer benefited from the overhead protection of the larger trees. It has been observed repeatedly on other clear-cut areas that heavy accumulations of snow on the crowns bends and eventually breaks or throws these smaller and relatively isolated trees.

Finally, the question may be raised whether wind damage will continue on these areas, or whether it has taken out the weaklings and the stand has now become adjusted to the changed conditions that follow logging. This question can be answered conclusively only after subsequent investigations. On two of the areas wind damage was checked twice. On Johnson Mountain a record was made 2 years after cutting, and at that time 75 percent of the ultimate damage had already been incurred. In T5 R18 the first examination was also made 2 years after cutting, but there only 30 percent of the ultimate wind losses had already occurred. The results lead to no conclusions, especially when it is remembered that in November 1950 the whole of northern Maine and northern New Hampshire was hit by an exceptionally high wind.

The conclusion drawn from these experimental cuttings is this: the forest manager should not let fear of wind damage discourage him from adopting partial cutting in all-aged stands. The losses are not great; and with good silviculture the losses should be less than the gain from increased growth.

SUMMARY

Wind damage to spruce and fir trees left after selective cutting was studied on five areas in Maine and northern New Hampshire, for an average period of $3\frac{1}{2}$ years after cutting.

Losses averaged 0.12 cord of merchantable spruce and fir per acre per year, or 1.4 percent of the volume. Wind damage increased sharply when more than 20 percent of the total basal area of all species was taken out in logging.

There was no apparent difference in losses between softwood and mixedwood types. More than 60 percent of the damage to fir was caused by breakage, while two-thirds of the spruce losses were due to uprooting.

Fir was nearly three times as susceptible to wind damage as spruce. Large fir trees were especially vulnerable: on one tract 18 percent of the residual trees of more than 12 inches d.b.h. were destroyed, as compared with 11 percent of trees over 9 inches and 3 percent of trees between 6 and 9 inches.

The larger the openings made for yards and roads, the greater the damage. Very tall trees of either species were highly vulnerable.

Fear of wind damage need not be a deterrent to selective cutting in spruce-fir stands. Losses should be small if a few simple precautions are followed.

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